Physiographic Study of Java Island Based on EMAG2 v3 Data

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ABSTRACT

This study aims to analyze the physiography of Java Island based on the Earth Magnetic Anomaly Grid version 3 (EMAG2 v3) satellite data. The EMAG2 v3 dataset represents a global magnetic anomaly compilation acquired from satellite measurements provided by the National Oceanic and Atmospheric Administration (NOAA). The magnetic method, a geophysical technique that utilizes variations in the Earth's magnetic field anomalies, was employed to delineate subsurface geological structures. The datasets used include administrative maps, regional geological maps, physiographic maps, and magnetic anomaly maps derived from EMAG2 v3 processing. Data processing was performed using the Geosoft Oasis Montaj software to generate the magnetic anomaly map of Java Island. The results indicate that the magnetic anomaly values across Java Island range from −300 nT to 450 nT, showing spatial variations among different physiographic zones. The northern part of Java exhibits low to moderate magnetic anomalies that correlate with alluvial deposits and young sedimentary formations, while the southern part displays moderate to high anomalies, reflecting the presence of volcanic rocks and intrusive bodies. This analysis demonstrates a strong correlation between magnetic anomaly variations and the lithological as well as structural characteristics of each physiographic zone. Therefore, EMAG2 v3 data can be effectively utilized to comprehensively interpret the regional geological framework of Java Island.

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1. INTRODUCTION

Indonesia is an archipelagic country located at the convergence of three major tectonic plates: the Eurasian, Indo-Australian, and Pacific Plates. This tectonic setting results in intense volcanic and seismic activity, producing complex geological structures across the region [1], [2]. Java Island, one of the main islands of Indonesia, possesses distinctive physiographic characteristics that reflect its long and dynamic geological history. Extending approximately 1,000 km from west to east with an average width of 200 km, the island is composed of several physiographic zones formed through the interaction of tectonic, volcanic, and sedimentary processes [3].

According to Van Bemmelen [4], the physiography of Java Island is divided into several major zones, namely the Southern Mountains Zone, Central Depression Zone, Quaternary Volcanic Zone, Bogor Anticlinorium Zone, and Northern Alluvial Plain Zone. This physiographic division represents variations in lithology, structure, and morphology among distinct geological units. The southern region is predominantly composed of older sedimentary rocks and altered volcanic formations, whereas the northern part is dominated by young sedimentary rocks and alluvial deposits [5].

Physiographic studies are crucial for understanding the relationship between surface morphology and subsurface geological structures. One of the most effective geophysical methods for such analysis is the magnetic method, which utilizes variations in the Earth's magnetic field anomalies to distinguish magnetic properties of rocks [6]. Magnetic anomaly values can be interpreted to infer geological structures such as faults, folds, and intrusive bodies [7].

Regional magnetic data can now be obtained from satellite-based measurements. One of the widely used datasets is the Earth Magnetic Anomaly Grid (EMAG2) version 3, developed by the National Oceanic and Atmospheric Administration (NOAA). This dataset integrates magnetic survey data from marine, airborne, and satellite observations with a spatial resolution of 2 arc-minutes and an observation altitude of 4 km above the geoid [8]. The utilization of EMAG2 v3 data provides significant advantages in physiographic analysis, as it can depict regional magnetic anomaly variations consistently across Java Island [9].

This study aims to analyze the physiography of Java Island using EMAG2 version 3 data. The analysis focuses on identifying magnetic anomaly variations in each physiographic zone and interpreting their correlation with the regional geological framework of Java Island.

2. METHODS

2.1. Data Source dan Research Location

This research employs a magnetic geophysical approach using secondary data from the Earth Magnetic Anomaly Grid version 3 (EMAG2 v3), published by the National Oceanic and Atmospheric Administration (NOAA) through the National Centers for Environmental Information (NCEI) [8]. The EMAG2 v3 dataset has a spatial resolution of 2 arc-minutes with an observation altitude of 4 km above the geoid. The dataset has been corrected for the Earth's main magnetic field, thereby representing only the total magnetic anomaly values.

Supporting data include the physiographic map of Java Island based on the classification by Van Bemmelen [4] and the regional geological map from the Geological Agency (PSG, 2019). The physiographic map was used to examine the correlation between magnetic anomaly patterns and major surface morphology, whereas the geological map served to strengthen the interpretation of subsurface lithology.

The study area covers the entire Java Island, geographically located between 105°–115° E and 6°–9° S (Figure 1). Java Island extends approximately 1,000 km from west to east and consists of several main physiographic units, namely the Southern Mountains Zone, Central Depression Zone, Quaternary Volcanic Zone, Bogor Anticlinorium Zone, and Northern Alluvial Plain Zone [4], [5].

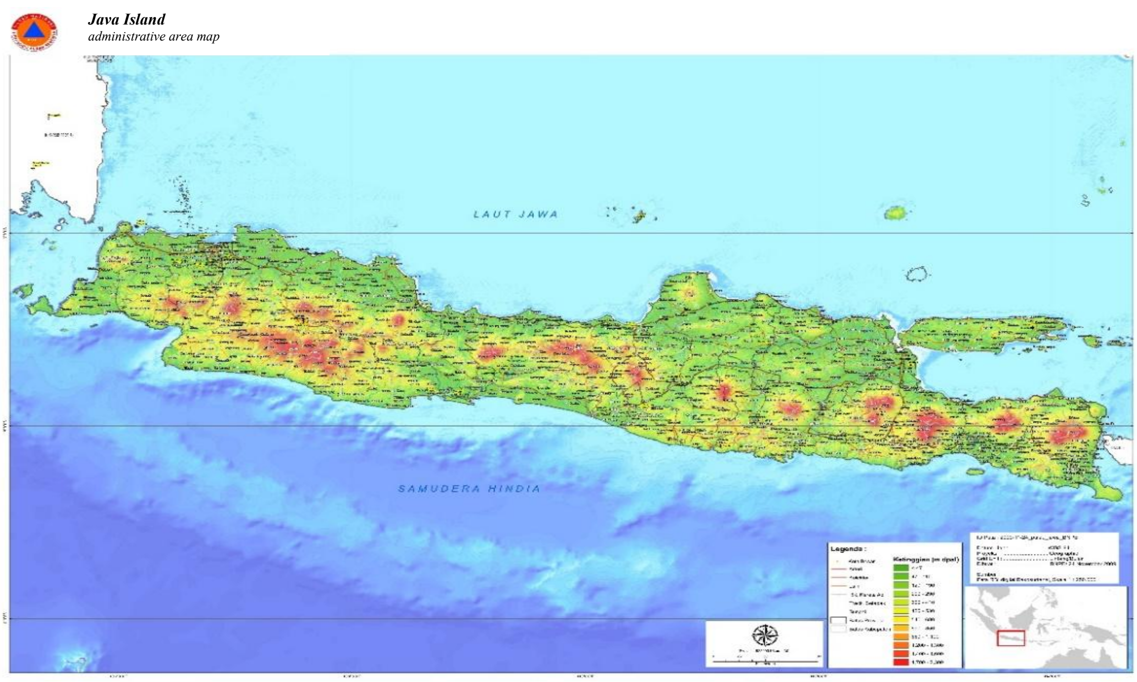

Figure 1. Administrative Map of Java

2.2. Data Processing

Data processing was carried out using Geosoft Oasis Montaj software version 9.9. The EMAG2 v3 data, obtained in grid format, were first clipped according to the boundary coordinates of Java Island to focus on the study area. Subsequently, a gridding process using the minimum curvature method was applied to produce a smooth and representative total magnetic anomaly map that reflects the magnetic field conditions over Java Island.

The next step involved applying the Reduction to the Pole (RTP) filter to correct for the inclination effect of the Earth's magnetic field. This process aims to shift the anomalies to a vertical position so that the magnetic anomaly values are directly located above their respective sources [7]. The upward continuation process was then applied to emphasize regional anomaly patterns and suppress shallow local effects [10]. The results of these processing steps were visualized in the form of a regional magnetic anomaly map with a color scale representing magnetic field intensity variations, ranging from low (blue) to high (red).

2.3. Interpretation of EMAG2 v3 Data and Java Physiography

Interpretation was conducted by comparing the EMAG2 v3 magnetic anomaly map with the physiographic map of Java Island. The objective was to identify the relationship between variations in magnetic anomaly values and the physiographic and lithological characteristics of each zone.

Zones with low magnetic anomalies are generally found in the northern part of Java Island, which consists of young sedimentary rocks and alluvial deposits. In contrast, moderate to high magnetic anomalies occur in the southern part, composed of volcanic rocks and strongly magnetized intrusions [9].

Qualitative interpretation was carried out by identifying the boundaries of anomaly value variations, which were assumed to represent contacts between different rock units or geological structural zones. The interpretation results were then compared with the physiographic divisions proposed by Van Bemmelen [4] to ensure consistency between geophysical data and surface morphology conditions. This analysis serves as a basis for understanding the relationship between the regional magnetic field and the physiography of Java Island from a geological perspective.

3. RESULTS AND DISCUSSION

3.1. The EMAG2 v3 Magnetic Anomaly Map

The results of the EMAG2 v3 data processing indicate that the total magnetic anomaly values across Java Island range from −300 nT to 450 nT. The generated magnetic anomaly map (Figure 2) displays spatial variations in anomaly distribution extending from west to east. High anomaly values are generally concentrated in the southern part of Java Island, whereas low anomalies dominate the northern region. These variations reflect differences in the magnetic properties of the underlying rocks, which represent the geological and lithological conditions within each physiographic zone, as illustrated in Figure 3 [7], [8].

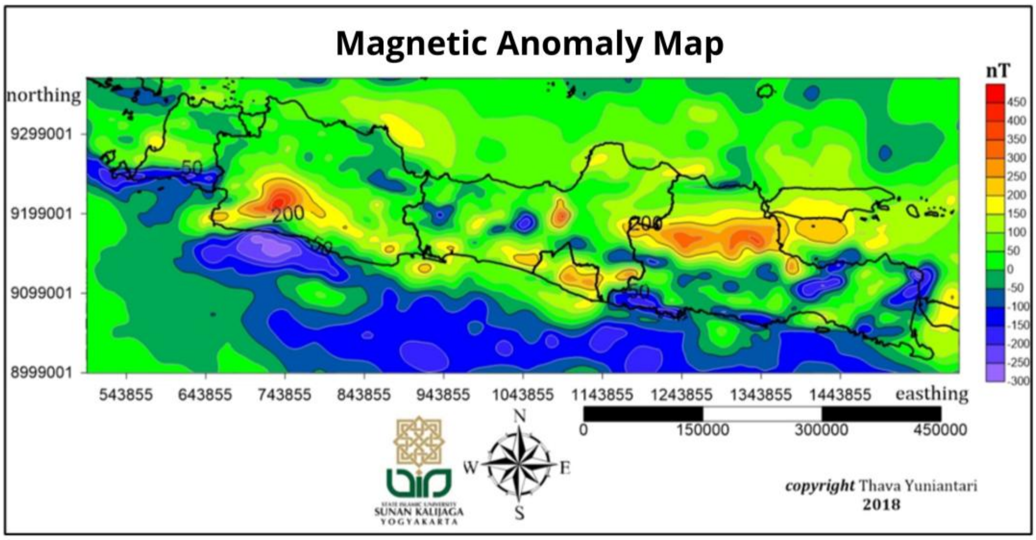

Figure 2. Magnetic Anomaly Map

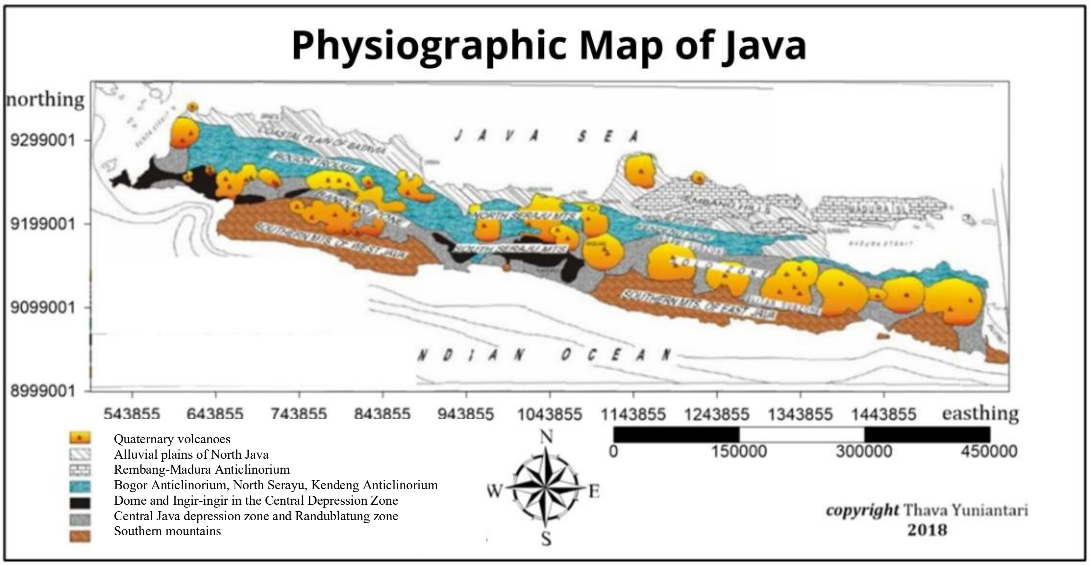

Figure 3. Physiographic Map of Java

The northern part of Java Island exhibits low to moderate magnetic anomaly values (−200 nT to 50 nT), which correlate with alluvial deposits and young sedimentary rocks. This pattern is consistent with the studies of Van Bemmelen [4] and Srijono [5], who stated that the physiography of northern Java consists of lowlands formed by recent deposits resulting from erosion and sedimentation processes. In contrast, the southern part of Java Island shows moderate to high anomaly values (150–450 nT), indicating the presence of volcanic rocks, intrusive bodies, and altered igneous rocks. The elongated high-anomaly zone in the southern region is associated with the Southern Mountains Zone, which is known to be composed of volcanic rocks ranging in age from Tertiary to Quaternary [11].

3.2. Magnetic Anomaly Variation Analysis by Physiographic Zones

Physiographic analysis based on the EMAG2 v3 map reveals five major zones of Java Island, namely the Southern Mountains Zone, the Central Depression Zone, the Quaternary Volcanic Zone, the Bogor Anticlinorium Zone, and the Northern Java Alluvial Zone [3]. The Southern Mountains Zone exhibits high anomaly values (200–450 nT), which are attributed to the presence of strongly magnetized volcanic and intrusive rocks. Hamilton [1] and Hall [3] explained that this zone is the result of intense tectonic and magmatic activities caused by the subduction of the Indo-Australian Plate beneath the Eurasian Plate south of Java.

The Central Depression Zone is dominated by low to moderate anomalies (−100 nT to 150 nT). Geologically, this area consists of clastic sedimentary deposits and volcanic materials that have accumulated over older basin structures [6]. The Quaternary Volcanic Zone shows moderate to high anomalies with circular patterns following the distribution of active volcanoes. This is consistent with the findings of Husein et al. [9], who reported that high anomalies in Quaternary volcanic regions are associated with the presence of young, highly magnetized igneous rocks. The Bogor Anticlinorium Zone displays fluctuating moderate anomaly values, reflecting complex folding and fault structures in the western part of Java Island [12]. The Northern Java Alluvial Zone has the lowest anomaly values (−300 nT to 50 nT), corresponding to the characteristics of young Quaternary sedimentary rocks that are non-magnetic in nature [5], [13].

The comparison between the EMAG2 v3 magnetic anomaly map and the physiographic division shows a strong correlation between magnetic anomaly patterns and regional morphotectonic conditions. The high anomaly patterns in the southern part indicate areas of magmatic intrusions and intense volcanic activity, whereas the low anomalies in the northern part represent zones of sedimentation and quaternary deposit accumulation.

3.3. Regional Geological Interpretation of Java Island

The EMAG2 v3 analysis results indicate that variations in magnetic anomaly values across Java Island reflect complex tectonic and volcanic processes. The high anomalies observed in the southern region are closely related to the Java magmatic arc, which is a result of the subduction of the Indo-Australian Plate beneath the

Eurasian Plate [1], [3], [14]. This subduction activity has triggered the formation of intrusive igneous rocks within the Southern Mountains Zone and enhanced the magnetic properties of rocks in this area.

Meanwhile, the low anomaly values in the northern region represent a relatively stable zone that has not undergone significant deformation. This zone is composed of non-magnetic sedimentary rocks and alluvial deposits derived from erosional processes in the central and southern parts of Java Island [15]. These results are consistent with the interpretations of Hall [3] and Husein et al. [9], who stated that the physiography of northern Java reflects a passive tectonic environment dominated by sedimentary processes.

Overall, the interpretation of the EMAG2 v3 data demonstrates that the magnetic anomaly patterns of Java Island are strongly correlated with regional physiographic divisions. The contrast in anomaly values between the northern and southern regions illustrates differences in lithology, structural configuration, and levels of tectonic and volcanic activity. Thus, the EMAG2 v3 data have proven effective for regional physiographic analysis and support geological mapping based on magnetic imagery in Indonesia [10], [16].

4. CONCLUSION

The analysis of EMAG2 version 3 magnetic data reveals that variations in magnetic anomaly values across Java Island are closely related to regional physiographic and geological conditions. The magnetic anomaly values within the study area range from −300 nT to 450 nT, with distribution patterns that reflect differences in rock characteristics across the respective physiographic zones.

The northern part of Java Island is dominated by low to moderate anomaly values associated with alluvial deposits and young sedimentary rocks, whereas the southern part exhibits moderate to high anomalies, indicating the presence of volcanic and highly magnetized intrusive rocks. This relationship demonstrates that the EMAG2 v3 data are effective for identifying lithological variations and subsurface geological structures influencing the physiographic formation of Java Island.

Overall, this study confirms that magnetic anomaly variations can serve as a primary indicator in physiographic analysis and regional geological interpretation. These findings may provide a foundation for future studies integrating magnetic data with gravity or seismic data to obtain a more comprehensive understanding of subsurface structures.

DECLARATION

Author Contribution

T. Yuniantari and H. Rosyida, processed the experimental data, performed the analysis, drafted the manuscript and designed the figure. T.A Niyartama and M.F Zakaria was involved in planning and supervised the work. All authors discussed the results and commented on the manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

[1] W. Hamilton, “Tectonics of the Indonesian Region,” U.S. Geological Survey Professional Paper 1078, Washington D.C., 1979.
[2] L. D. Setijadji, “Volcanostratigraphy and geochemistry of volcanic rocks in Central Java,” Indonesian Journal of Geoscience, vol. 8, no. 1, pp. 1–18, 2013.
[3] R. Hall, “Late Jurassic–Cenozoic reconstruction of the Indonesian region and the Indian Ocean,” *Tectonophysics*, vol. 570–571, pp. 1–41, 2012.
[4] R. W. Van Bemmelen, “The Geology of Indonesia”, Vol. 1A. The Hague: Government Printing Office, 1949.
[5] Srijono, “Tektonik dan Geologi Pulau Jawa,” *Jurnal Geologi Indonesia*, vol. 3, no. 2, pp. 65–78, 2007.
[6] D. L. Turcotte, and G. Schubert, “Geodynamics,” 2nd ed., Cambridge University Press, 2002.
[7] W. M. Telford, L. P. Geldart, and R.E Sheriff, Applied Geophysics, 2nd ed., Cambridge: Cambridge University Press, 1990.

[8] NOAA, "Earth Magnetic Anomaly Grid (EMAG2) v3 Data Release," National Centers for Environmental Information (NCEI), 2017.
[9] S. Husein, S. Widiyantoro, and B. J. Santosa, "Analisis Fisiografi dan Struktur Geologi Pulau Jawa Berdasarkan Data Geofisika," *Jurnal Geofisika Eksplorasi Indonesia*, vol. 3, no. 1, pp. 45–54, 2013.
[10] R. J. Blakely, "Potential Theory in Gravity and Magnetic Applications," Cambridge University Press, 1996.
[11] A. J. Pannekoek, "Geomorphology and Tectonic Evolution of Java," *Journal of the Geological Society*, vol. 106, no. 4, pp. 289–302, 1950.
[12] A. Raharjo, "Struktur Lipatan dan Sesar di Zona Antiklinorium Bogor Berdasarkan Data Geologi dan Geofisika," *Jurnal Geosains Indonesia*, vol. 5, no. 2, pp. 99–110, 2015.
[13] R. Soeria-Atmadja, "Quaternary volcanism in Java," *Bulletin of the Geological Research and Development Centre*, vol. 6, pp. 1–45, 1983.
[14] R. Hall, and H. R. Smyth, "Cenozoic arc processes in Indonesia: Identification of the key features," *Geological Society of London Special Publications*, vol. 355, pp. 145–173, 2011.
[15] S. Husein, "Analisis Medan Magnet Regional Pulau Jawa Berdasarkan Data Satelit," *Jurnal Eksplorasi Geofisika*, vol. 4, no. 2, pp. 21–32, 2018.
[16] T. O. Simandjuntak, and A. J. Barber, "Contrasting tectonic styles in the Neogene orogenic belts of Indonesia," Proceedings of the Indonesian Petroleum Association, vol. 22, pp. 51–66, 1993.